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SOLAR ASSET MANAGEMENT

WHITE PAPER ///

Making Solar Smarter

Current & Future AI Applications

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1. Executive Summary

"Anything that could give rise to smarter-than-human intelligence—in the form of Artificial Intelligence, brain-computer interfaces, or neuroscience-based human intelligence enhancement - wins hands down beyond contest as doing the most to change the world. Nothing else is even in the same league."

—

Eliezer Yudkowsky

Artificial Intelligence (AI) has increasingly become the hype and hope of this tech-driven age with Machine Learning (ML) and Internet of Things (IoT) at its very foundation. More and more of today's interactions are powered by AI, from the gadgets we use to the cars we drive. In addition, AI has had an immense impact on how natural resources such as energy, food and water, are sourced and delivered, amongst them the energy generated by the rays of sunshine. Although the integration of the energy industry and artificial intelligence is still very much in its infancy, their synergy has the potential to radically revolutionise the existing power generation practices across the globe. The rapid advancements in ML, data processing, IoT and further expansion of sensor markets are among some of the main contributing factors in realising the true promise of AI. If the mantra of solar is that "The fuel is free; let's reduce other costs", artificial intelligence powered solutions can be the holy grail solar has been seeking.

2. A brief guide to artificial intelligence

The latest advances in Artificial Intelligence (AI) and Machine Learning (ML) have ushered a new era driven by automation. AI is defined as a realm in computer science, which emphasises the creation of intelligent machines akin to human beings in terms of behaviour and response capabilities such as speech-recognition, planning and problem- solving. Overall, there are two key pillars comprising the existing body of research in artificial intelligence, one of which is knowledge engineering. Machines have the ability to behave and respond similar to human beings only if they are provided with extensive information relating to the world they are surrounded with. Another core pillar of artificial intelligence is machine learning (ML), which enables computers to manage new situations by means of analysis, observation, self-training and experience. AI and ML are often used interchangeably and wrongfully so. Machine learning is merely an aspect of the current application of artificial intelligence, rooted in the notion that computers should be given access to data and provided with the opportunity to learn for themselves. Robotics is also another major discipline related to the field of AI, as robots necessitate intelligence to manage tasks including manipulation, motion planning and mapping.

Adoption pattern

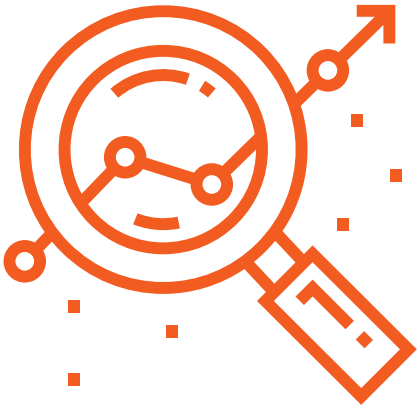
Despite the swift developments in AI technology, widespread adoption has yet to be achieved. This makes for a challenging assessment of the exact magnitude of the impact, which AI can have on companies and business sectors. Nevertheless, there are still a number of early adopters who have implemented artificial intelligence and are reaping its lucrative benefits. According to McKinsey global Institute, these early adopters tend to be primarily part of the tech sector. In

addition, they conclude that AI can particularly deliver value to companies, which are inclined to utilise it within their core functions as well as across operations. Their survey illustrates that early AI adopters, combining strong digital capability with proactive strategies, experience a higher profit margin and may expect an increase in their performance gap with other companies over the next three years. High-tech and telecom companies as well as financial services are amongst the companies leading artificial intelligence and hold the most ambitious investment plans concerning AI. In addition to the type of industry, there is also a geographic spread. Companies located in the United States consumed 66% of all external investments into artificial intelligence in 2016. China held the second position with 17% and is growing rapidly.

Over the course of the coming few years, artificial intelligence is poised to radically alter the way businesses in all industries are conducted. Currently, machine learning applications and artificial intelligence analyse significant amounts of structured and unstructured data. Moreover, these applications are able to generate insights within a fraction of the time and at a fraction of the cost of human labour. AI is no longer solely a sci-fi and futurologist phenomenon, but an actual business tool to boost productivity and economic growth. Therefore, the real question is: 'How will AI deliver value to businesses and in specific, the solar industry?'.

3. Data: AI's central enabler

Despite all the advances made in computing capabilities, algorithms and data-accessibility, it can be well argued that data is still the most critical component of actualising AI, as without it all the other elements would be merely a string of impressive technology requiring substantial human input. The artificial intelligence machines become smarter when supplied with not only a greater amount of



data but also more aggregated data. Moreover, the less human intervention is required, the smarter the engine becomes, which reduces the gap between businesses and true promise of artificial intelligence.

Data aggregation for better solar asset management

Simply utilising spreadsheets to manage assets is neither a lasting nor an efficient approach for a number of reasons. According to PowerHub, a leading asset management platform for renewable energy professionals, the primary concern is the reliability issues associated with software like Excel. These issues include potential insecure information access, invalid data entries, accidental data deletion and corrupted files. A plausible way to avoid these reliability issues can be cloud based asset management. The second reason would be the lack of centralisation and the significant margin of error that occur when multiple people edit the same spreadsheet. Excel files are extremely easy to rename, move, copy, resave and so forth. This can lead to multiple versions of the same sheet circling around. Centralised systems such as PowerHub can assist in cataloguing the information to guarantee that solely authorised individuals are able to view what they need. In addition, PowerHub enables multiple users to have simultaneous access to information, whereas Excel allows users input data on a one-at-a-time basis. Providing constant manual updates

is another disadvantage of utilising Excel in lieu of automated data. Additionally, having a more centralised pool of data enhances the company's overall efficiency, particularly in terms of decision making. Data mining can be a tedious and burdensome task if the data is scattered over various files and, even worse, different formats. Therefore, it is imperative to master the art of data collection and maintenance.

4. Smart solutions

In order to lower the cost of generating energy from the sun, the industry should focus on decreasing the costs associated with O&M, as the fuel, rays of sunshine, comes at no cost. A significant portion of these costs can be minimised by means of AI, through better tracking, monitoring and evaluating data from solar plants. In fact, data could put the world on the cusp of transitioning from utilising planet-harming fuel to clean energy produced by sun. kWh Analytics, a leading provider of risk management software and services, created a new piece of solar software in 2016 that uses data from solar projects all around the globe in order to persuade insurance companies to support a production guarantee. Part of kWh Analytics' offering is a software tool called 'Heliostats', which is designed specifically to meet the needs of financial institutions. This platform includes data integration, portfolio analysis, benchmarking and reporting.

Weather forecasting

In an effort to further drive down the costs, a number of tech giants, including IBM, are actualising ways to make solar cheaper by means of data. In 2016, IBM acquired The Weather Company, with the aim of providing the "most accurate weather forecasts globally with personalised and actionable insights". Prior to that, IBM had already started working on discovering ways to enhance the accuracy of existing forecasting methods from analysing cloud and car movement to solar cameras. Forecasts of utmost accuracy are highly advantageous for reliable grid operations while maintaining low costs. As a result, IBM has achieved the capacity to prognosticate wind and solar conditions from approximately 15 minutes to a month in advance. This technology is developed based on a situation-dependent blending model, which essentially blends several unique forecasting models (figure 1). The model combines the data collected from multiple sources including environmental and atmospheric conditions, like temperature, wind, cloud properties, etc. The aforementioned model has been applied to a number of forecasting issues and cases

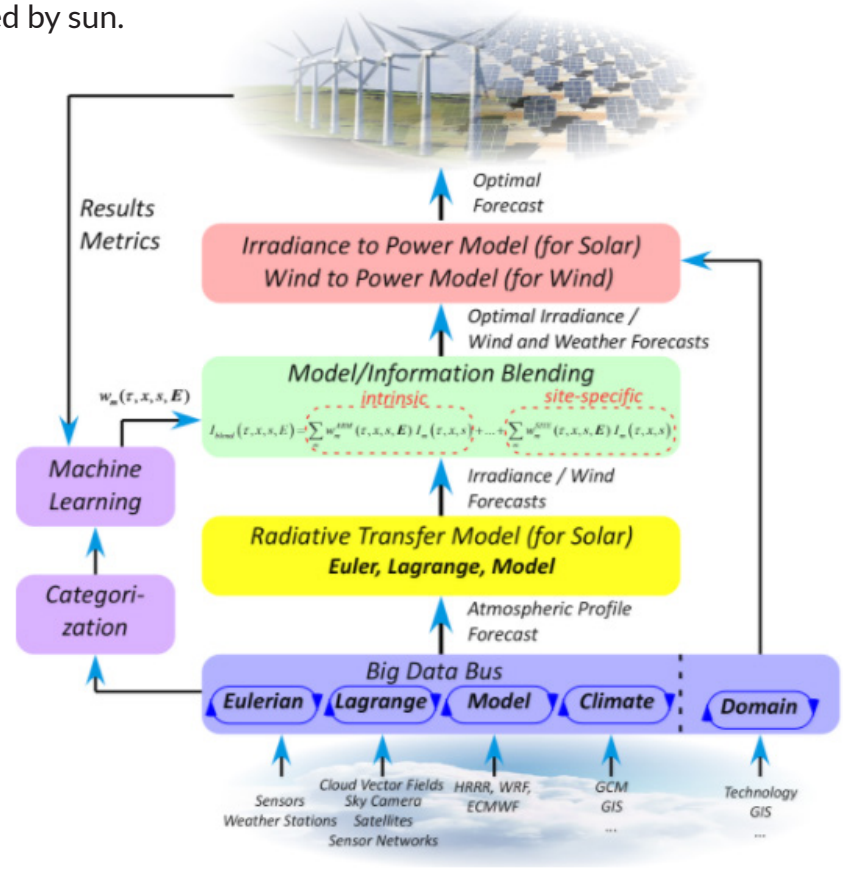


Figure 1: Architectural view of situation-dependent, machine learning based multi-model blending.

in diverse geographical locations. Significant forecast accuracy improvements have been observed in all cases, mostly over 30%.

In the theme of forecasting, the National Centre for Atmospheric Research (NCAR) is another prominent contributor to the AI surge making advances in the realm of solar power forecasting. This project entails examining the forecasts in multiple geographically- as well as climatologically- diverse utilities with high solar penetration and ISOs. NCAR regards forecasting as a value chain, starting with the weather "causing deviation from clear sky irradiance and progresses through monitoring and observations, modelling, forecasting, dissemination and communication of the forecasts, interpretation of the forecast, and through decision- making , which produces outcomes that have an economic value". NCAR has collaborated with a number of partners on this project, from government labs and universities to utilities and independent system providers like Xcel Energy. Another innovative solution in the field of solar forecasting is Nnergix PVforecast, which utilises AI technology by means of data mining processes and is targeted at any energy or electric player in the industry.

Failure forecasting

General Electric, a leader in the field of power generation, has allocated tremendous amounts of resources towards developing software that can analyse sensor data. This resulting software is called 'Predix' and utilises AI to optimise efficiency and predict failure prior to occurrence. Predix has been deployed by energy giant Exelon Generation to enhance power plant reliability and performance. Predix combines sophisticated asset modelling, real-time big data processing, analytics and applications, and encompasses great security measures. Invenergy, North America's largest privately held renewable energy company, has also partnered with General Electric to employ GE's solar asset performance management (APM) software, which was coupled by Predix with a solar farm with the capacity of 20 MW. The official deployment was expected to begin at the end of 2017. Furthermore, this agreement entails formation of a 'digital twin' or, in other words, a replica of an actual physical asset created by means of ML algorithms, which enables the operators to improve the asset management services. This virtual doppelgänger supplies a blueprint of a "fully-functional" plant, which can then be used as a benchmark to identify data anomalies. Having these real-time insights provides the possibility of alerting the operators in advance to avert potential failures and thus expanding the availability of the plant. Enhanced plant availability can lead to a reduction in O&M costs, as well as an increase in production. According to Azeez Mohammed, president and CEO of GE's Power Conversion, for a 20-MW solar project, this improvement in the availability of the plant translates into an additional $200,000 worth of value per annum. By virtue of these AI-driven insights into asset performance, condition-based maintenance can replace the conventional calendar-based approach. The condition-based method is an advanced maintenance method, which is executed when truly needed and before the asset is down. Therefore, the repair time can be scheduled post-sunset, which further cuts the downtime and retrieves the energy lost otherwise.

Yield enhancement

Furthermore, it is possible to deploy algorithms in order to examine production data of power plants and compare them against models to improve yields. DeepSolar technology, developed by Raycatch, is a "state-of-the art algorithm service" and a prime example of an AI application aimed at optimising the yield. This technology requires no hardware and software installations as well as no site visits.

Making the grid smarter

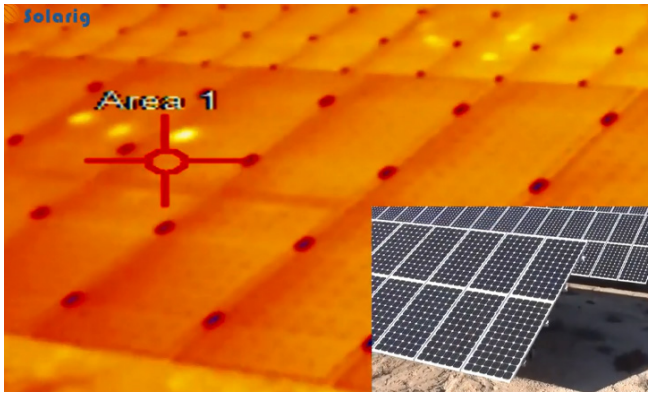
AI will undeniably be at the forefront of modernising the grid in order to make it "smarter". These vanguard technologies will be able to continuously gather and contextualise astonishing amounts of data from millions of sensors to optimise the decision-making process regarding the allocation of energy resources. Consequently, specialised microgrids will supplant enormous regional grids, which can also be combined with advanced battery technologies enabling power to flow continually to and between local communities even in cases of extreme weather. In essence, artificial intelligence will enable the U.S. to transition to an energy portfolio with an expanded renewable source production, as well as minute disruptions from the intermittency inherent in these resources due to the fluctuations in sunlight and wind intensity.

The U.S. Department of energy (DOE) has made it a national policy goal to support the creation of "smarter" grids, which has also been legislatively endorsed by the Energy Independence and Security Act (EISA). According to DOE, the smart grid involves "two-way communication technologies, control systems, and computer processing". These cutting-edge technologies include sensors called Phasor Measurement Units (PMUs), which enable operators to examine the stability of the grid. These sensors allow digital meters to supply customers with better information and report outages automatically. In addition, PMUs assist the grid in sensing and automatically recovering from faults in the substation, as well as providing batteries, which store the excess energy. Since 2010, the DOE has installed over 15 million smart meters, which audit energy usage per individual device and inform utilities in case of local blackouts.

5. Robotics & Renewables

Robotics are an inescapable focus when debating the impacts of AI on solar - or renewables in general - and is growing swiftly. There are a plethora of discussions and speculations on how robots will influence people's lives - negatively or positively. Robotics experts believe that robots will be able to fully replace the dull, dirty and dangerous tasks for humans, which are referred to as the 3Ds of robotisation. Suffice it to say that the applications of robotics in the solar industry adhere to the same principle, and robots are utilised for tasks encompassing the aforementioned 3Ds. Autonomously operated robots will raise the ante in terms of effectiveness and efficiency of solar operations with the proper implementation.

A prime instance of utilising robots in the solar industry is the use of flying drones for conducting inspections of a PV plant. These drones are presumably the most advanced of the robots used in renewables. The majority of these drones carry a high-resolution video camera and thus can supply images to detect dirt, cracks and other incongruities, even in presence of severe weather conditions. In



addition, most premium drones are capable to carry thermal/infrared imaging cameras, which can unveil an abundance of new information that is impossible to obtain otherwise. Solarig, a global solar photovoltaic integrator, is an example of an O&M company that currently offers drone thermal inspection of PV plants. Their inspection service promises to lead to a precise diagnosis as well as a cost-effective solution. As an alternative to drones, fixed-wing aircrafts can also be utilised for site inspections.

Regardless of the type of the camera, the inspection images produced need to be analysed quickly and in real-time, which requires dexterous analysis tools. The latest advances in the discipline of deep learning, another branch of artificial intelligence, facilitate the deep learning networks, once trained, to conduct in-actual time analysis of the images. Deep learning is particularly beneficial while dealing with data accounting for a substantial number of discrete values such as speech and image recognition. An example would be distinguishing between images of solar panels, with or without various type of cracks. Overall, AI-supported analysis will become the chief instrument as far as efficient and effective inspection of solar plants are concerned.

6. O&M issues and AI solutions: A case study

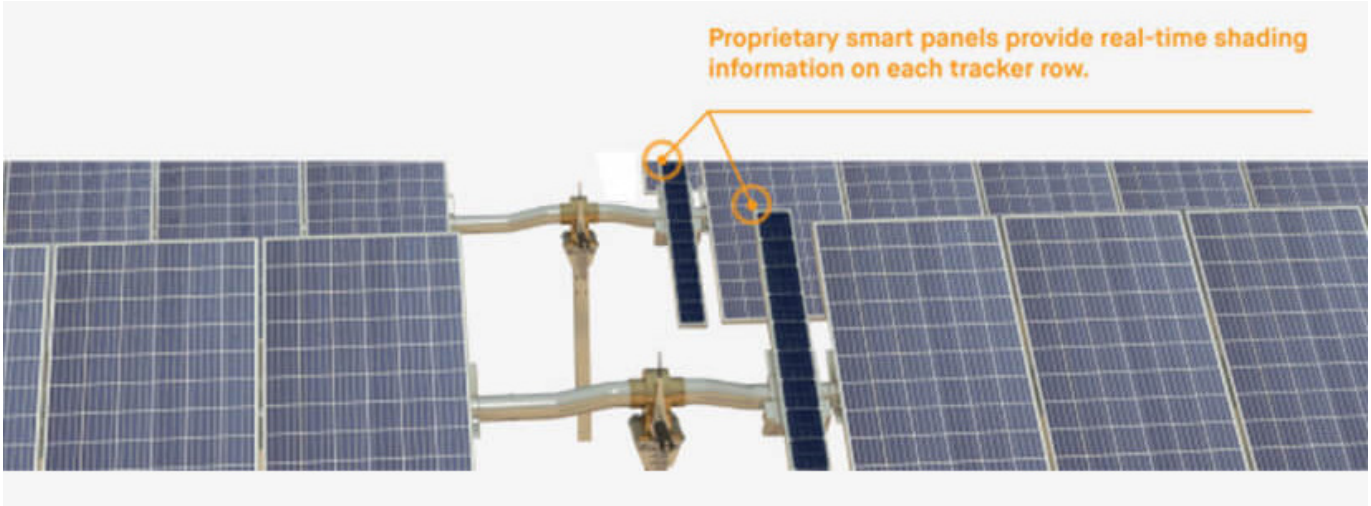
Krypton has conducted a case study with SunPower, a global leader in solar power systems, to examine the impact of AI on a series of challenges they have been faced with. One of these challenges is rooted in the swift increasing number of power plants, which they control and monitor. This has also led to a substantial rise in the volume of data generated from these solar assets. This continuous stream of data is usually transferred into different data stores and operator tools. Therefore, SunPower would be obligated to employ multiple software tools in order to achieve insights into underlying data and - ultimately - equipment issues. This can lead to alert fatigue in systems and may impede operators from effectively performing their tasks. SunPower had initially built a number of internal software tools to assist their operators in such matters, nevertheless those tools were also floundering under the burden of the enlarged load. Another challenge SunPower was faced with, is the staggering hardware expense required, given the growing amount of data as these tools run on a database with a single-server architecture. In order to overcome the aforestated issues and tremendously enhance their efficiency, SunPower had to resort to new and even more innovative solutions driven by AI and so their engagement with Krypton began.

Krypton's offering to SunPower was to "learn from every O&M data point" to extract the most value from the abundance of data they had acquired. Krypton's specific solution was a product called 'Krypton Collect', which utilises data agents to centralise the data from multiple systems including SCADA systems. Moreover, the modern distributed architecture of Krypton Collect creates instant access to the data and searchability of it. Another Krypton service deployed by SunPower was the 'Krypton Decision Engine', which allowed the company to process billions of data points on a daily basis and consequently detect issues much more effectively and instantaneously.

7. IoT & AI on the horizon of solar

The Internet of Things (IoT) is fundamentally transforming solar installations on a component level, by embedding them with advanced software and, more importantly, sensors. Therefore, the components will become a network, which collects and exchanges data, and ultimately supplies the essential algorithms for AI. This data will be particularly useful in terms of research and development (R&D). The conventional product designs are largely based on static modeling and laboratory results. Furthermore, given the recent advancements in ML, solar hardware could potentially become capable of troubleshooting without human intervention. Another example is that of irradiance-based tracking systems, which have existed for decades, but were nevertheless generally disregarded, due to reliability issues concerning soiling and shading. This can now be changed by designing a new generation of tracking systems based on algorithms. Such tracker systems can recognise patterns in the data collected by the sensors over the course of time. For instance, the tracker system might recognise that, when a certain wind speed hits the system at a specific degree tilt, the system becomes distressed. Proceeding forward, the system could alert the array to change tilt angle anytime the sensors register that the wind is approaching. Similarly, the system can move back into the ideal tilt angle as the wind diminishes. Overall, ML and AI are set to foster a new breed of solar machines, which are smarter and possess increasingly optimised designs.

In July 2017, NEXTracker introduced a new tracker control system called 'TrueCapture', supported by the predictive BrightBox Technologies, described as "an intelligent, self-adjusting tracker control system that increases typical PV power plant energy by 2-6%". TrueCapture continually improves the tracking algorithm of each row according to site characteristics and weather conditions, whereas standard systems track all the rows equally. "Proprietary smart panel sensors provide real-time shading information on each tracker row", the data of which is then processed by an ML software in order to construct a virtual 3D model of the plant site. The intelligent control engine of TrueCapture combines this virtual model with the most recent meteorological forecast data to compute and transfer upgraded tracking instructions to each solitary row, resulting in increased energy production.



Closing Words

How swiftly the full potential of AI will be realised for solar is simply an issue of debate. Nonetheless, AI will certainly have an immense impact on the solar business. Therefore, embracing AI powered solar technologies is not only a prudent decision but a necessary one to be able to cope with the possible disruptions of business models in the industry.

Learn more about the implications and potential of AI and meet the companies applying the latest O&M technologies at the fifth annual edition of Solar Asset Management: North America, the leading platform on the operational phase of solar assets, set to take place on March 13&14 in San Francisco. Learn more on the website: https://solarassetmanagement.us/

– Mina Mesbahi, Solarplaza

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